ITT

Corrugated Mirrors for Segmented Astronomical Telescopes

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Engineered for life

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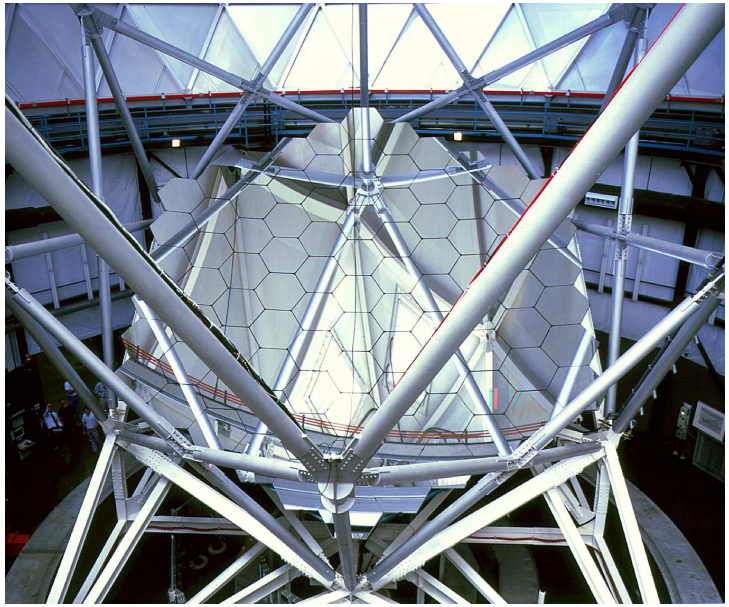
Agenda

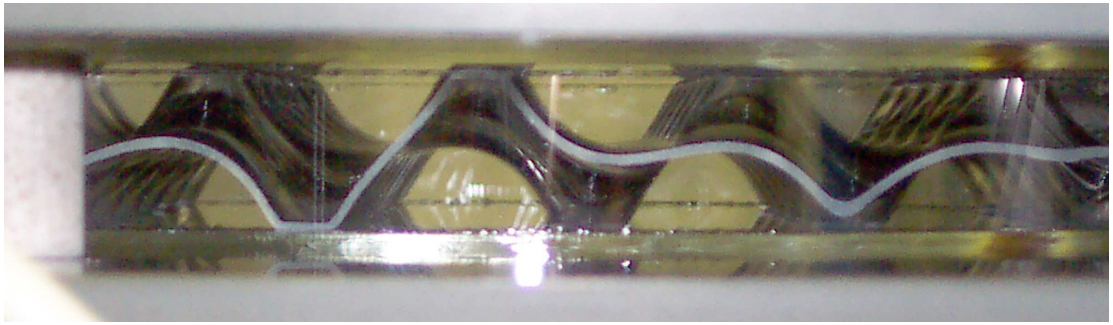
- ITT segmented astronomical telescope heritage
- Corrugated mirrors
  - Concept
  - Demonstrations
  - Strength
  - Replication
- Corrugated mirror point designs
- Summary

ITT Large Segmented Telescope Heritage

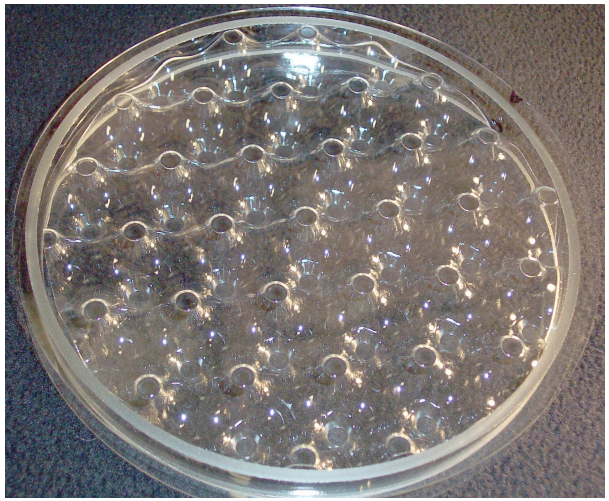
- SALT, HET
  - Spherical primary mirror, 11.1 x 9.8 m
  - 91 1.0 m segments
  - ITT delivered:
    - Mounted PM segments + spares
- KECK I & II
  - 10 m aspheric PM,
    36 1.8 m segments
  - ITT final figured 81 PM segments

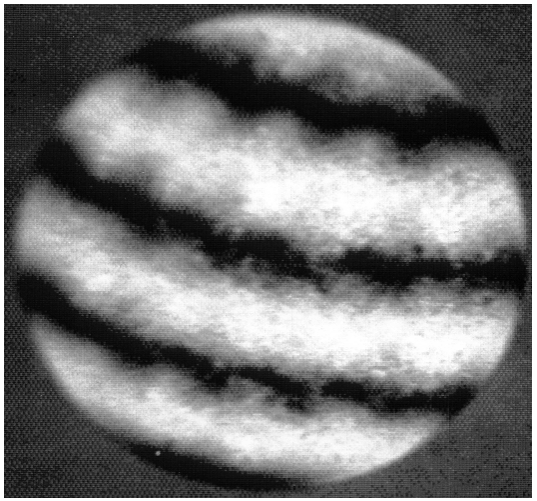


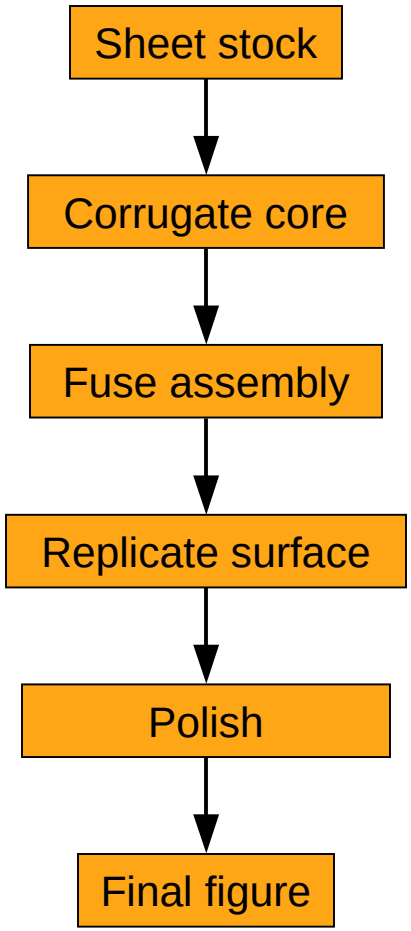
60 nm RMS Lightweight Mirror In 5 Days



- 58 nm RMS / 310 nm P-V
- <10 Kg/m², 150mm diam, plano surface, borosilicate
- Molded surface ± 2um – minimal post processing
- Ready for ion figuring

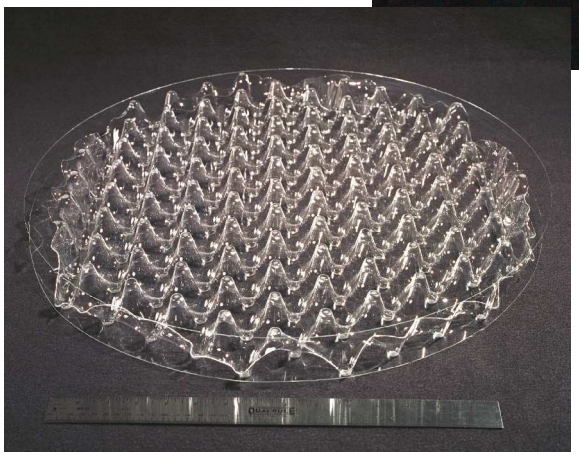






Corrugated mirror

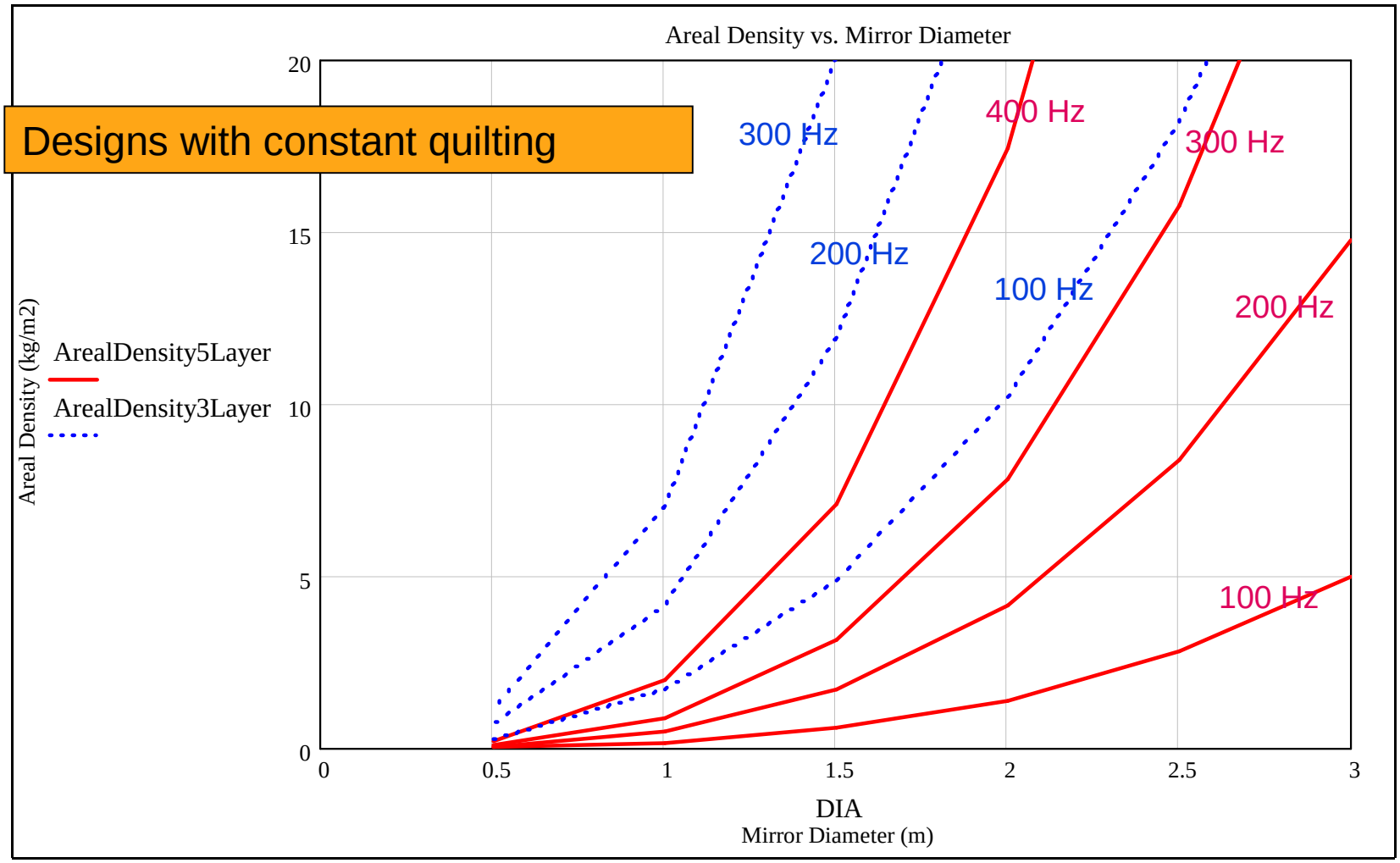
- 0.5 m diameter, 50 mm deep
- <5 kg/m^2
- 3 layer design
- 2 day fabrication cycle



Corrugated mirror

- 0.5 m diameter
- 8 kg/m^2
- >1000 Hz first mode
- <40 nm RMS 1-g sag on 3 points
- <30 nm RMS quilting at 1 psi
- 5 layer design
- 5 day blank fabrication cycle

Significant Advantage from 5 Layer Mirror Design

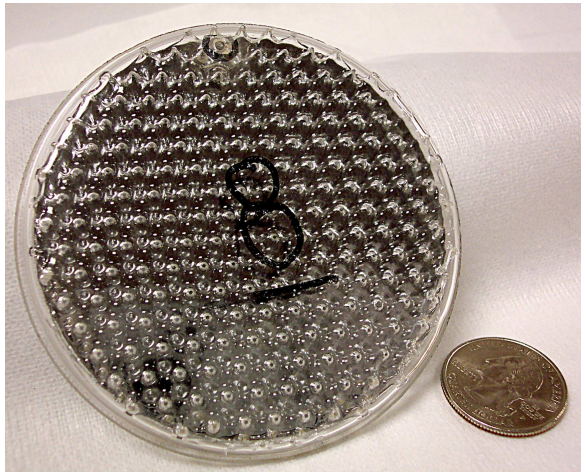


Strength Testing

- 4.7 kg/m^2 mirror
- 700 µm thick borosilicate glass
- 72 kg load

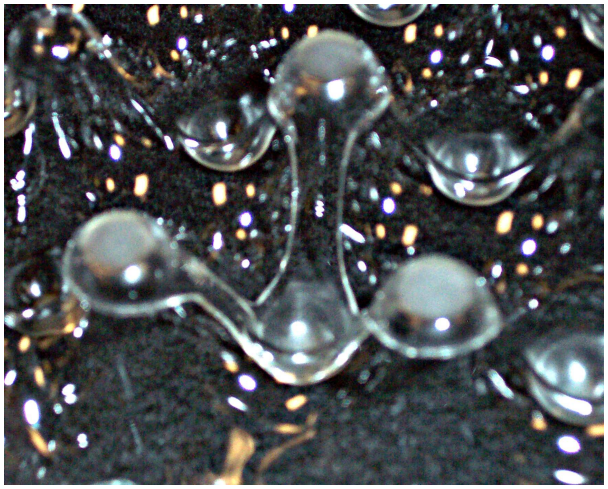
Strength Testing

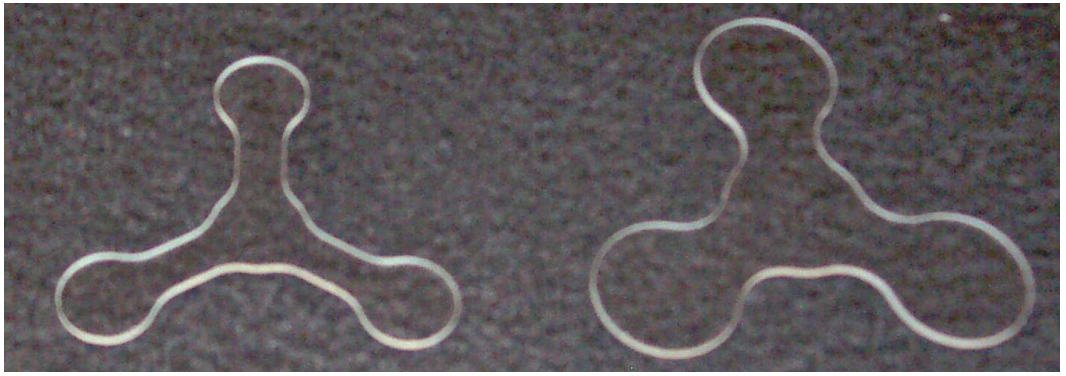
- 75 mm diameter 3-layer corrugated mirror
- Areal density: 5 kg/m^2 – 22 g mass
- Inflation test: >1300 N (~6000x weight)
- Compression test: >2200 N (~10000x weight)
  - top load uniform
  - bottom support 65 mm ring
- Surface error 28 nm RMS (ready for ion)
- Surface roughness 5 – 13Å RMS
- Fabrication time – 12 mirrors in 13 days



Mount point reinforcement

- Support forces concentrated at mount points
- Demonstrated local reinforcement
  - Core and faceplates
- Add material only where needed
- High temperature fused, high strength bonds





Optically replicated surfaces

<5 µm departure from best fit sphere

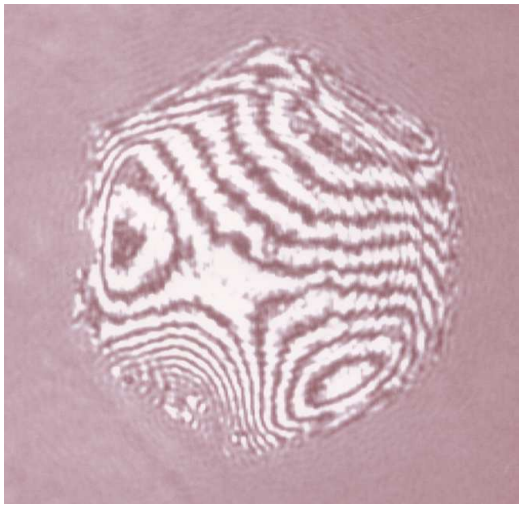
1-2 nm RMS roughness

- Chapman 5 mm scan, 10x objective

235 mm hexagonal part

3 mm thick borosilicate glass

5 m radius sphere



Interferogram shown is at normal incidence,

632.8 nm wavelength

Central ring pattern is an interferometer ghost

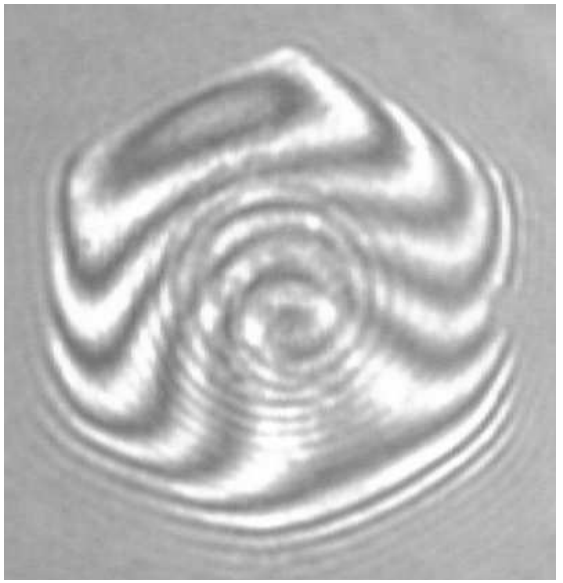
Optically replicated surfaces

<1.5 µm departure from best fit sphere

235 mm hexagonal part

20 mm thick borosilicate glass

5 m radius sphere



Interferogram shown is at normal incidence,
632.8 nm wavelength
Central ring pattern is an interferometer ghost

ULE corrugated mirrors

225 mm ULE blank

~8 Kg/m^2

1mm Thick

ULE

38mm Deep

Cycle time comparison

- AMSD ~1 year

- Production corrugated mirror ~8 weeks

  - Blank is rapidly fabricated
  - Replication eliminates generate, grind, polish, some of figuring
  - Performance is improved
    - Trade areal density, 1-g sag / first mode frequency, quilting
  - Gains are achieved through nonrecurring tooling
    - Process designed for volume production

CCAT segment point design

7 rings, 187 segments

3-layer corrugated mirror design

1.8 m segments, 2 mm thick glass

~85 mm deep core

~75 mm corrugation spacing

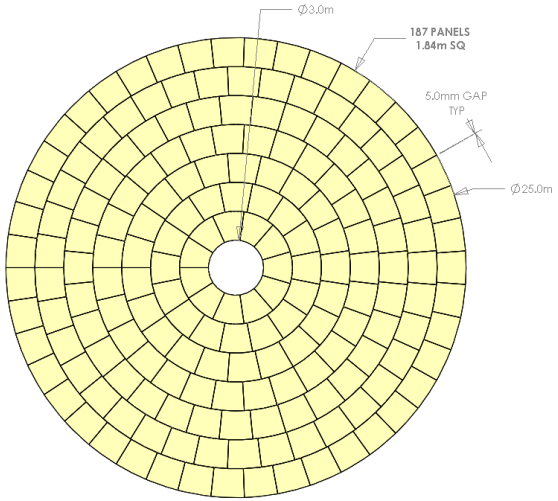
<14 kg/m^2

~180 Hz first mode frequency

<2 µm RMS gravity sag on 3 points

Acceptable robustness, manufacturability

Uses available borosilicate glass



25 m visible wavelength telescope point design

7 rings, 187 segments

5-layer corrugated mirror design

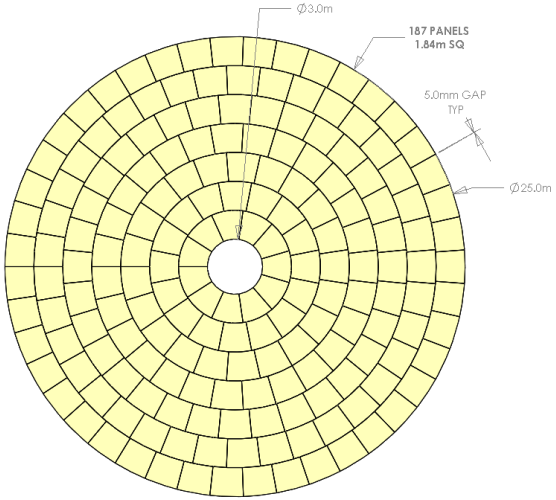
1.8 m segments

2.4 mm thick glass

<30 kg/m^2

~570 Hz first mode frequency

<200 nm RMS gravity sag on 3 points



Multipoint supports would allow significantly lower gravity sag

45 nm RMS gravity sag on 9 points

Acceptable quilting, manufacturability

Requires ULE glass for visible wavelength applications

Corrugated Mirror Summary

- New manufacturing technology
  - Designed for volume manufacturing of mirrors
- Substantially lower cost
- Substantially shorter cycle times
- Significantly improved performance

- Enables production of astronomical mirror segments

- Enabling technology for segmented mirror telescopes
  - Development will continue…